Availability of decentralized inverter concept of PV power system in Ubon Ratchathani, Thailand

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Abstract

This article presents the availability of decentralized inverter concept of PV power system located at Tambon Sakkapoloom, Muangsamsib District, UbonRatchathani province of Thailand. The 1MW PV system consists of 255numbers of 4kW decentralized inverters. The data used in calculation process was collected from 1st February 2013 to 31st January 2014. The results of this research found that the average availability of the decentralized inverter concept in PV power system was 99.98% while in centralized inverter concept it was 97.47%. However, the evaluation period of only 1 year when compared with the life time of these PV power plants. The different failure characteristic of these PV power plants that always happen in every month for decentralized system and rarely happen in a year for centralized system were also dominated availability of these PV power plants. So, it is possible that availability of these PV power plants may not be different or availability of centralized system becomes better than decentralized system, depending on the evaluation period. This result can be used for feasibility study of centralized and decentralized PV power plants for Thailand in the future.

Keywords: *Availability, decentralized inverter, centralized inverter, photovoltaic system*

1. Introduction

Global warming and Carbon emission are the biggest challenges, facing our society today. In all parts of the world nations are expressing their commitments to preserve the nature and promote renewable energy. Solar energy has been a major area of focus worldwide because it is freely available, can be used directly and no harmful emission. In case of Thailand, good amount of funding had been allotted to solar energy especially photovoltaic (PV) power plant.

In 2007, Thai government announced an incentive in the form of adder, a system where the subsidy applied on top of the base electricity cost, of 8 Baht per kWh. As a result, commercial PV power plant gained popularity dramatically which is continued until now. The installed capacity has crossed the psychological limit of 1 GW PV power systems in operation and is growing at a rapid rate [1].

As solar PV power system grew commercially, the focus has turned into electrical performance of the system in order to maximize the economic aspects. In order to achieve the highest level of economical yields, many electrical performances must be taken into consideration, among them, availability and reliability of the system is most important.

The better availability of the PV system, the better it yields commercially. Among all components of the PV power system, inverter is main factor and by far the most sensitive one; therefore, it is worthwhile to focus the study of availability of the PV power system on the inverter and its types. [2,3,5]

There are many studies already on the availability of PV power system applying centralized and decentralized inverter concept but the operating conditions like climate and environment was quite different from Thailand making them unusable here. The availability study of PV power system applying decentralized inverter concept will focus on central and string inverter configuration in the Thai climate and environment. The outcome of the study of availability and reliability of PV power system applying decentralized inverter concept will reveal a very useful knowledge to help improve commercial PV system in Thailand or even in many other regions of world with similar climatic conditions.

2. Selection of PV power systems

There are two main concepts of inverter to be applied in PV power system; centralized and decentralized. In centralized inverter concept a few large-scale inverters are used in centralized area such as a single control room, on the other hand, in decentralized inverter concept small inverters are used in different strings of PV modules. There are pros and cons for both concepts though they vary depending on location, climate, size of power plant, local regulations, investment, availability, future trend of supplies and usage of PV power system. The study will act as a useful decision making tool to determine best suited configuration for PV system under given situations.

The decentralized inverter PV power system for this study was selected from an existing 1MW solar power plant located in Tambon Sakkapoloom, Muangsamsib District, Ubon Ratchathani province of Thailand. From now on, this PV power system will be called decentralized system. For comparison reason, a separate centralized inverter PV power system of a similar size was selected. The selected 1.2MW centralized inverter solar power plant located at Tambon Thaklee, Thklee District, Nakhon Sawan province of Thailand. From now on, this PV power system will be called centralized system. Though both of the PV power systems are alike in size, there are some variations between the two which have been described in Table 1.

The hypothesis of this study is that centralized and decentralized PV systems play an important role in PV system availability. From the PV power plant samples, only PV power plant capacity is not different while other important factors are totally different. Therefore this study focuses on the failures caused only by the central inverter and string inverter effecting PV power plant availability while other factors have been taken beyond the scope of this study.

3. Configuration of the systems

Table 1: The configuration of the decentralized system compare with centralized system

Description	Decentralized system	Centralized system
Plant capacity	1 MW	1.2 MW
Module type	200W Crystalline Module	135 W Thin-Film Module
Inverter capacity	4 kW	500 kW 630 kW
Number of inverters	255	2 (500kW and 630kW)
Number of strings per inverter	2	500 kW Inverter : 297 630 kW Inverter : 358
Number of modules in a string	10	14
Number of years in operation	3	1
Area	16,000 Sq.m. (10 Rai)	36,800 Sq.m. (23 Rai)

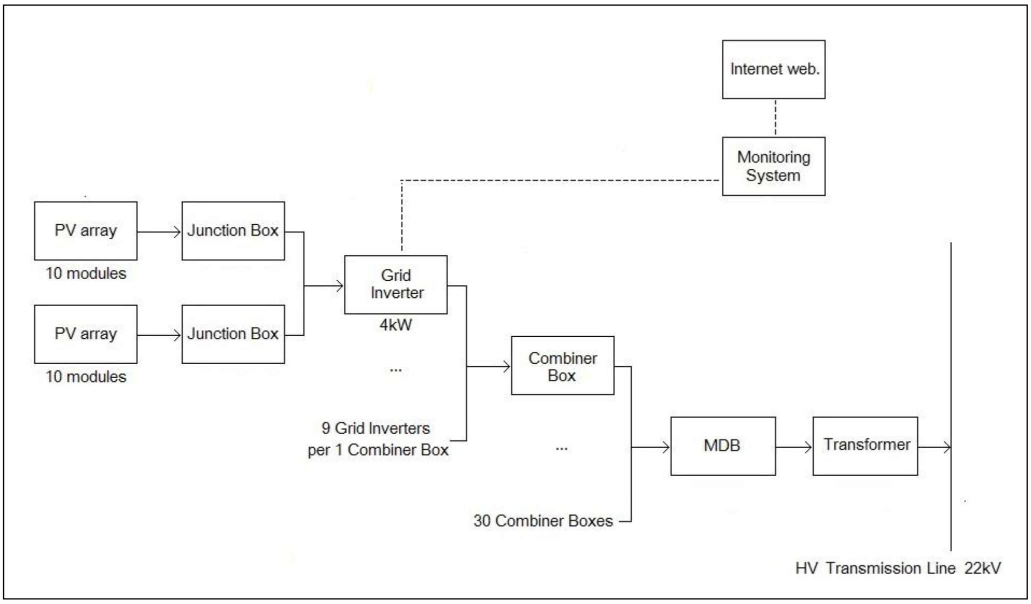


Figure 1 Single line diagram of decentralized system

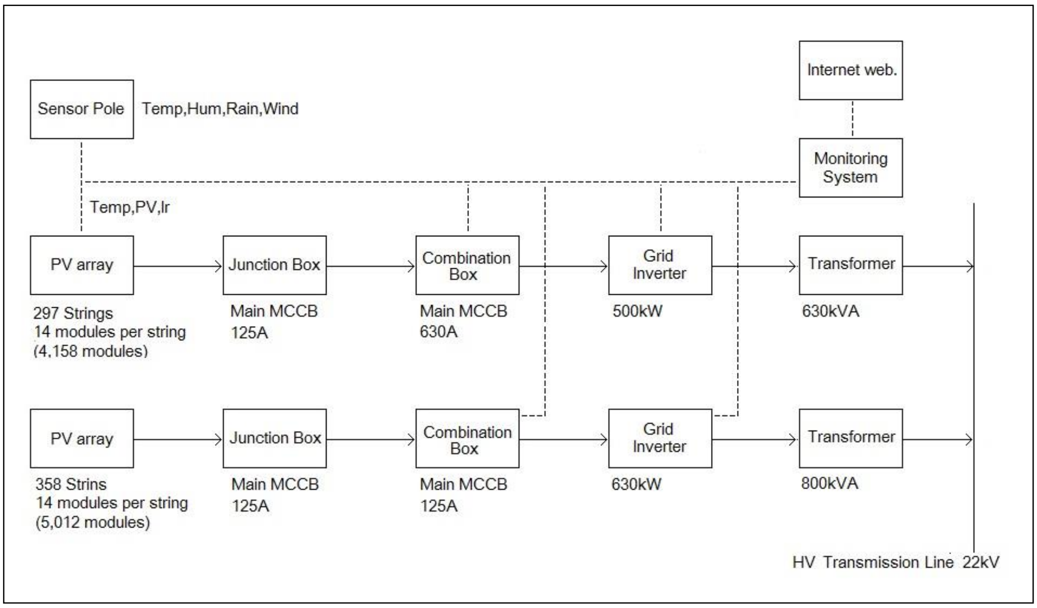


Figure 2 Single line diagram of centralized system.

4. Data collection

Since there is huge difference in number of inverters used between the centralized and decentralized systems, as decentralized system employs many more inverters than the centralized one, due to which, the operation and maintenance of each power plant has to be different to cope with the nature of the plants. The results of availability of both systems concluded from this study are not only the result of the availability of inverters, but also the result of the efficiency of the operation procedure of power plant maintenance.

The data collection method of this study was to collect the real records from both PV power systems according to the maintenance procedure of both power systems. The data was collected from both power systems during the same period of time from 1st February 2013 to 31st January 2014. The collected data was then used to calculate the average availability of both PV power systems. Table 2 shows examples of failures record from the decentralized system.

Table 2: Sample of inverters' error record from decentralized system

No.	Error Detected		Maintenance		Normal operation (Finish fixing)		Duration
	Date	Time	Date	Time	Date	Time	Hours
C3	2/Feb/2013	9:00 AM	2/Feb/2013	9:10 AM	2/Feb/2013	11:00 AM	2
M8	4/Feb/2013	9:00 AM	4/Feb/2013	9:10 AM	4/Feb/2013	11:00 AM	2
P7	7/Feb/2013	9:00 AM	7/Feb/2013	9:10 AM	7/Feb/2013	1:00 PM	4

For the Decentralized system, the record reveals the useful data that was needed to enter into the equations, used to calculate the availability of the PV power system. The major data was detection of error, starting time of response, and starting time of normal operation. Since there are so many inverters, the errors of inverters were detected very often, but it takes only an average of one hour to fix the error because the maintenance procedure of this power plant uses replacement method. The correction of the error must be implemented as soon as the error detected; therefore, in this case, a failed inverter was replaced by a new one within an average of one hour without any attempt to search for the cause of failure. The failed inverter that was taken away from operation then was analyzed for cause of failure and was sent out for repair.

For the Centralized system, the data collected from is shown in table 3.

Table 3: Sample of inverter's error record from centralized system

No.	Error Detected		Maintenance		Normal operation (Finish fixing)		Duration
	Date	Time	Date	Time	Date	Time	Hours
A	7/Jul/2013	7:00 AM	7/Jul/2013	8:00 AM	8/Jul/2013	7:00 AM	24
A	1/Sep/2013	9:00 AM	1/Sep/2013	9:35 AM	2/Sep/2013	9:00 AM	24
A	30/Dec/2013	9:00 AM	30/Dec/2013	9:40 AM	31/Dec/2013	9:00 AM	24

The useful data was collected and entered into the equation used for calculation of availability of the PV power system similar to that of the decentralized one described above. Since there are only two inverters for the whole system, the error rarely occurred. However, once it occurred, the operator cannot solve the problem by himself. The operator has to call for express maintenance service that can reach within the next 5-8 hours or even the next day. As a result, most of the error detected were fixed and back in operation by the next day.

The data collected for this study is solely done by the operators of each power plant according to their own operation and maintenance procedures. The operators were free from concerns of the outcome of this study while collecting the data; therefore, the data was provided accurately based on true operation of the plants.

5. Calculation of availability

Availability in percentage can be calculated from the equation 1:

$$Availability = \frac{m}{m+r} \times 100 = \frac{m}{T} \times 100 \qquad (1)$$

Where m is mean time to failure (MTTF) or duration of normal operation, r is mean time to repair (MTTR) or duration of failure operation, and T is total sun time including normal and failure operation (m+r). Normally, T is the period that the equipment could be called upon to perform its intended purpose. For clearer vision, T is the period where enough irradiance exists and all other external conditions are met (e.g. grid voltage within spec), the system will function as intended and produce rated power.

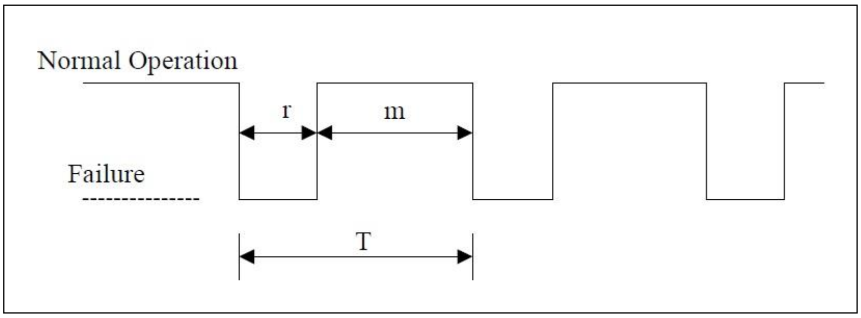


Figure 3 Definitions of system availability indices. [4]

The availability calculation shown above is Time Availability of the PV power system. It has not taken power loss due to failure time of the system into consideration. Since this study emphasized on the variation of inverter types, it is necessary to analyze further into power availability which is the availability of the PV power system due to power loss caused by failure.

6. Results and Discussions

6.1 Case of Decentralized system

An 80% Performance Ratio PR (20% loss, 80% gain) was applied due to variety of factors including temperature coefficient, module mismatching, component and cable losses. In addition, 80%PR is the normal PR value that is usually claimed in PV power plant performance guarantee from the EPC or operator of the PV power plant. Generally the capture loss (Losses from PV module temperature, DC cable, DC power system, etc.) is considered about 13- 15 % and system loss (Losses from inverter, AC cable, AC power system, transformer, etc.) about 5 – 7%, making a total of 20%.Therefore;

$T_{monthly}$ = Total inverter hours hrs.W
= Total inverter output × 80% Gain × Hours in each month hrs.W
= (255 × 4,000) × 0.8 × Hours in each month hrs.W

Duration of failure (r) was found from the data collected by the operator. Since the procedure of this PV power system clearly indicated that the correction of failure to be completed in 1 hour after the failure was detected, each failure took 1 hr to resume normal operation.

$r_{monthly}$ = Total inverter failure hours hrs.W

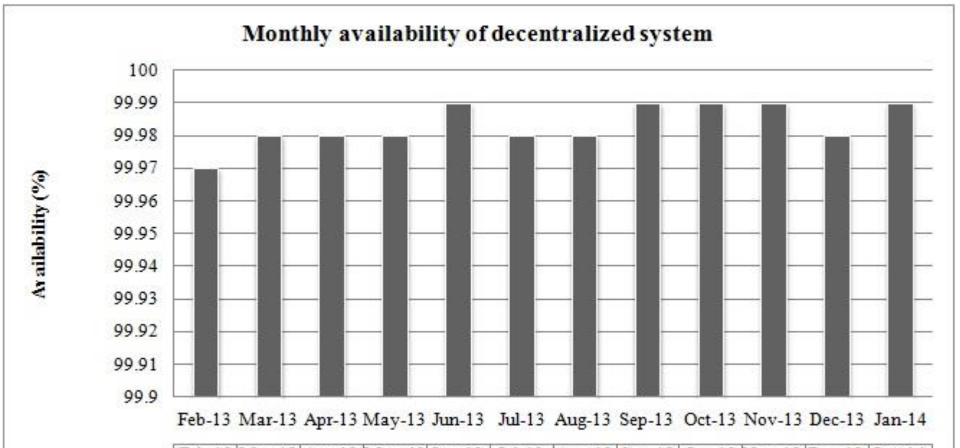
= No. of failure inverter × Failure hour × Inverter output hrs.W
= No. of failure inverter × Failure hour × 4000 hrs.W

$m_{monthly} = T_{monthly} - r_{monthly}$ hrs.W

Hence Availability (in percentage) is being calculated using equation 2.

$$Availability = \frac{m_{monthly}}{T_{monthly}} \times 100 \quad (2)$$

Availability of decentralized system calculated from the data recorded between 1st February 2013 and 31st January 2014 is shown in Figure 6. The average availability comes out to be 99.98 %.



	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14
Availability (%)	99.97	99.98	99.98	99.98	99.99	99.98	99.98	99.99	99.99	99.99	99.98	99.99

Figure 4 Availability of decentralized system

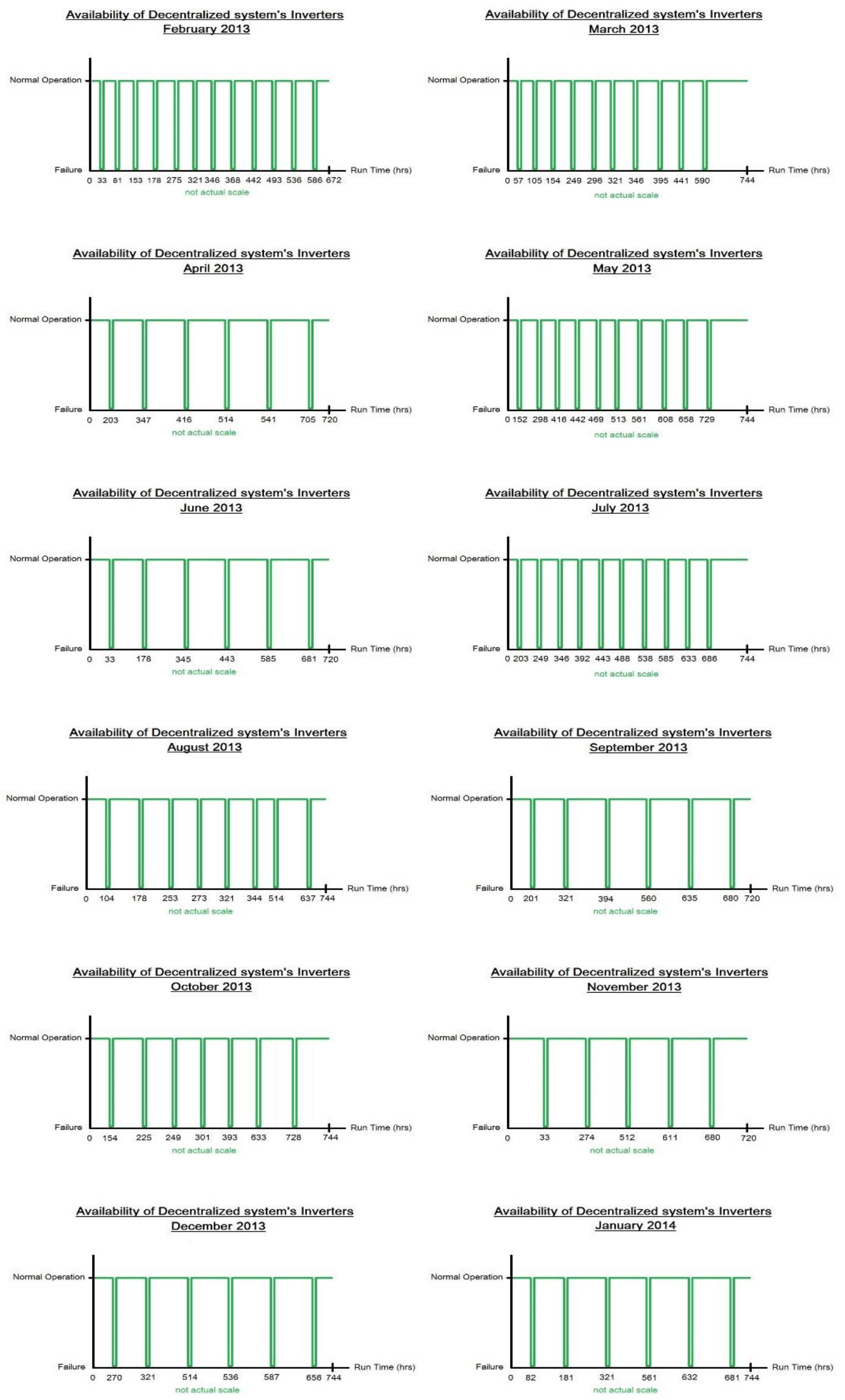


Figure 5 Monthly availability of decentralized system.

6.2 Case of Centralized system

There are only 2 inverters (500 kW and 630 kW) in this system, however, the 20% loss (80% gain) in power is taken due to variety of factors including temperature coefficient, module mismatching, component and cable losses; therefore

$$\begin{aligned} T_{\text{monthly}} &= \text{Total inverter hours} && \text{hrs.W} \\ &= \text{Total inverter output} \times 80\%\ \text{Gain} \times \text{Hours in each month} && \text{hrs.W} \\ &= (500{,}000 + 630{,}000) \times 0.80 \times \text{Hours in each month} && \text{hrs.W} \end{aligned}$$

Duration of failure (r) was found from the data collected by the operator. The data showed that the failure occurred only for 500kW inverter.

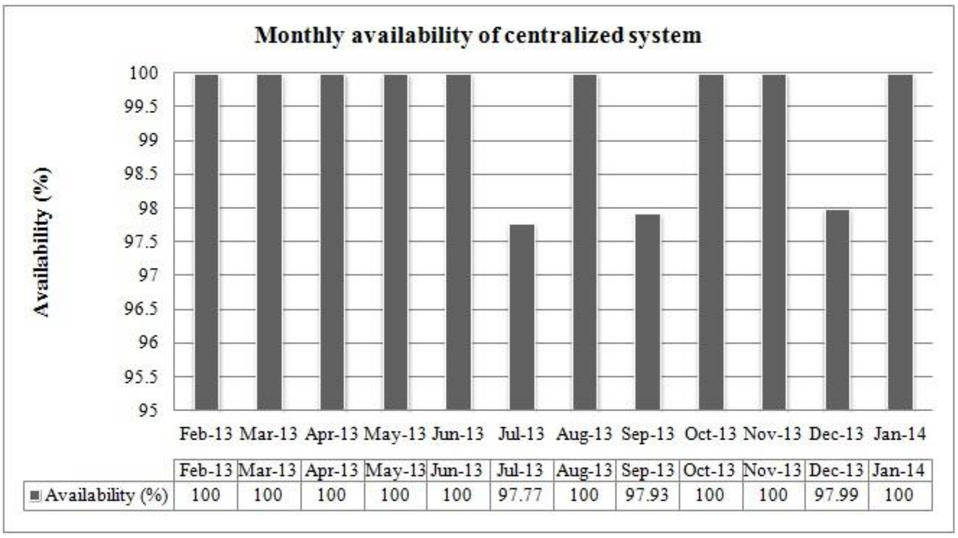
$$\begin{aligned} r_{\text{monthly}} &= \text{Total Inverter failure hours} && \text{hrs.W} \\ &= \text{Failure hour} \times 500{,}000 && \text{hrs.W} \end{aligned}$$

$$m_{\text{monthly}} = T_{\text{monthly}} - r_{\text{monthly}} \qquad \text{hrs.W}$$

Finding Availability (in percentage)

$$Availability = \frac{m_{monthly}}{T_{monthly}} \times 100$$

Availability of centralized system was calculated using the data recorded from 1st February 2013 to 31st January 2014 as shown in Figure 7. The average availability is 97.47 %.



	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14
Availability (%)	100	100	100	100	100	97.77	100	97.93	100	100	97.99	100

Figure 6 Availability of centralized system

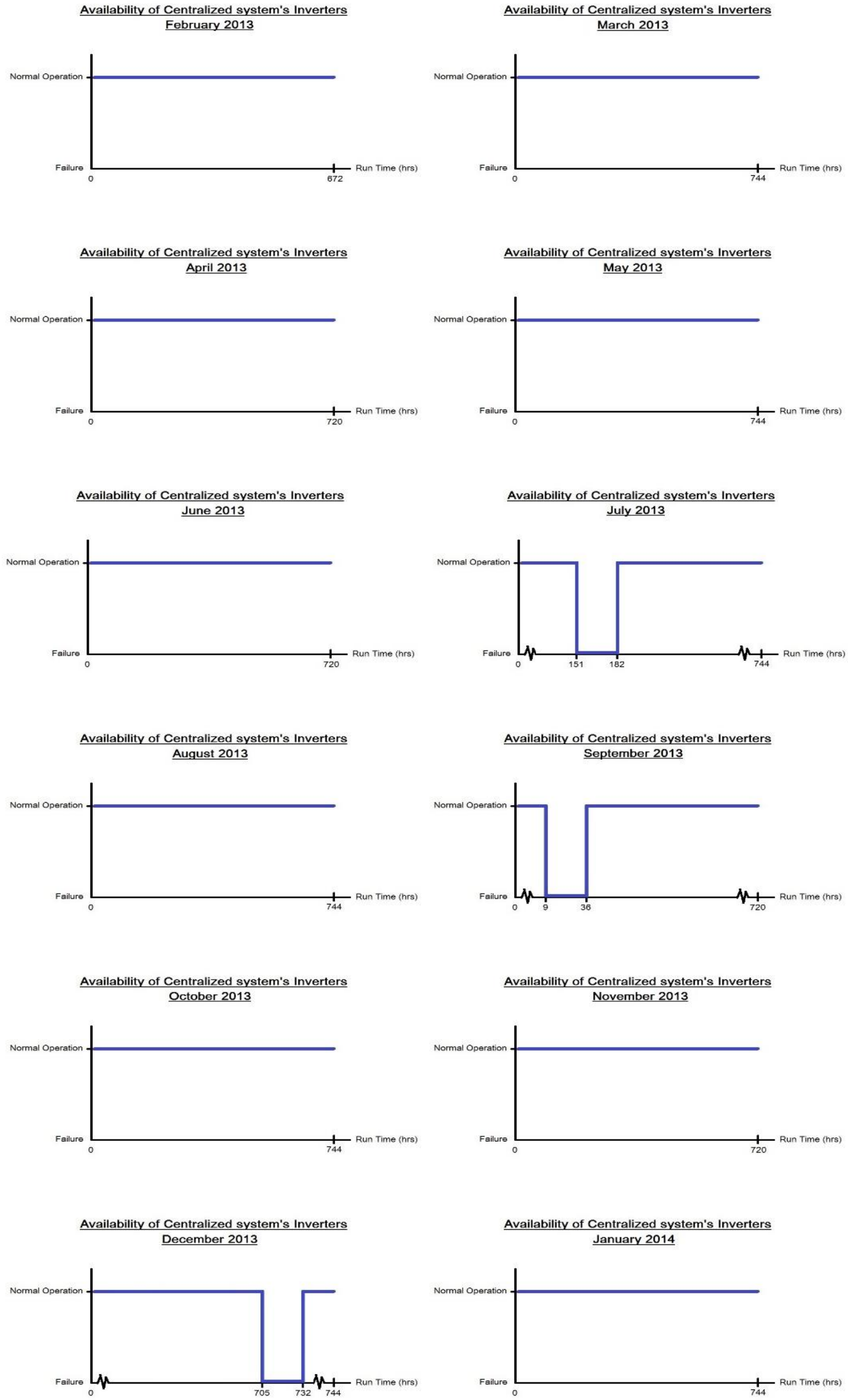


Figure 7 Monthly availability of centralized system.

From the result, availability of decentralized system is far better than centralized system. However, the evaluation period of only 1 year is too short when compared with the life time of these PV power plants i.e 25 years. In addition, the different failure characteristic of these PV power plants that always happen in every month for decentralized system and rarely happen in a year for centralized system dominate availability of these PV power plants. So, it is possible that availability of these PV power plants may not be different or availability of centralized system becomes better than decentralized system, depending on the evaluation period. The continuous study of availability of these PV power plants for their life time is recommended to get the accurate result. This result can be used for feasibility study of centralized and decentralized PV power plants for Thailand in the future.

7. Conclusions

The average availability of the selected PV power systems; the decentralized and the centralized systems were 99.98% and 97.47% respectively. This data revealed that the decentralized inverter concept showed a slight advantage over that of centralized one. Some of the main advantages of the decentralized inverter concept were that the inverters used in the system were small; therefore, the failure of one inverter had no significant impact on total system loss of power and take much less time to recover from failure compared to that of centralized system where the inverter has much bigger capacity and take more time to recover from failure.

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